Implementation and Research On the Operational Use of the Mesoscale Prediction Model COAMPS in Poland

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LONG-TERM GOALS

Our long-term goal is to implement an operational high-resolution atmospheric data assimilation system and to use it for daily weather forecasting. To date we have worked on several operational and scientific aspects of the problem using the Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS®[1]): (a) setting up stable large scale data transfer capabilities to facilitate COAMPS runs 2-4 times per day in an operational manner for different geographical regions and using different nested grid configurations; (b) perform research on the MPI scalability of COAMPS on selected computer architectures and to optimize the code to take advantage of the vector capabilities of the Cray X1 and the massively parallel features of our Linux cluster; (c) identify and understand the uncertainties in high-resolution NWP forecast and their impact on severe weather, such as extreme rainfall, and to develop model metrics appropriate to mesoscale, detailed weather forecasts; (d) improve our knowledge of observational error characteristics for spatially correlated data and develop the numerical schemes capable of assimilating these types of observations.

OBJECTIVES

The objectives of this project are to: (a) implement an operational data feed from the Navy Operational Global Atmospheric Prediction System (NOGAPS), and implement a semi-operational version of COAMPS at the Interdisciplinary Centre for Mathematical and Computational Modelling (ICM), Warsaw University; (b) validate COAMPS model performance through inter-comparisons with statistics obtained from the United Kingdom Meteorological Office (UKMO) unified model; (c) investigate the scalability of COAMPS on ICM computers, a 200-processor OPTERON cluster and a Cray X1; and (d) develop a data assimilation scheme that can assimilate remotely-sensed and non-conventional data sources with a special emphasis on Doppler radar data. Meeting these objectives will allow the Polish National Air Defense to issue 1-5 day mesoscale weather forecasts in the regions of their interest, including Poland and central Europe.

[1] COAMPS® is a registered trademark of the Naval Research Laboratory.

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14. ABSTRACT
Our long-term goal is to implement an operational high-resolution atmospheric data assimilation system and to use it for daily weather forecasting. To date we have worked on several operational and scientific aspects of the problem using the Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS?1): (a) setting up stable large scale data transfer capabilities to facilitate COAMPS runs 2-4 times per day in an operational manner for different geographical regions and using different nested grid configurations; (b) perform research on the MPI scalability of COAMPS on selected computer architectures and to optimize the code to take advantage of the vector capabilities of the Cray X1 and the massively parallel features of our Linux cluster; (c) identify and understand the uncertainties in high-resolution NWP forecast and their impact on severe weather, such as extreme rainfall, and to develop model metrics appropriate to mesoscale, detailed weather forecasts; (d) improve our knowledge of observational error characteristics for spatially correlated data and develop the numerical schemes capable of assimilating these types of observations.

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APPROACH

Our approach is to utilize NOGAPS for initial and lateral boundary conditions, and COAMSP for mesoscale atmospheric forecasts. The NOGAPS fields are obtained from the Global Ocean Data Assimilation Experiment (GODAE) server at the Fleet Numerical Meteorology and Oceanography Center (FNMOC) and transferred to ICM in automated (machine-controlled) efficient and stable way thanks to support of FNMOC. We will port the COAMPS system to the ICM Linux cluster and Cray X1 computers and measure system performance and scalability using tools developed in-house for model verification. The unique aspect of our capabilities is that we concurrently run UKMO mesoscale model on the grid which is similar to one that of COAMPS. We will also investigate the time evolution of the conditional forecast (background) error probability density function using an ensemble of the model forecast to generate background error statistics. This helps us to identify and understand the uncertainties in high-resolution NWP forecast on high impact weather, particularly extreme rainfall. Finally, we will study observational error characteristics of radar reflectivity and radar radial winds. Such observations have the potential to provide detailed information to improve mesoscale analyses and forecast. We will study historical weather events for which we have radar data to understand the observational error characteristics. We will investigate how they may be applied in data analyses used for assimilating radar data into numerical weather prediction models.

WORK COMPLETED

During FY05 we accomplished the following tasks: (a) installed, tested, and tuned the US NAVY COAMPS system on ICM machines at Warsaw University; (b) established and developed a stable data transfer capability so that we now run the COAMPS system two times a day in an operational manner, (c) developed tools for graphical model display, (d) collected radar data for post analysis, (e) developed stable numerical methods for advection-diffusion problems (Witek et al., 2005), and (f) implemented and developed tools to assimilate radar reflectivity and radial wind data using the ensemble Kalman filter approach (Jakubiak, 2005) in COAMPS.

RESULTS

During the first year of this project, we implemented the COAMPS atmospheric model on several computer architectures, investigated model scalability including MPI, established operational procedures, wrote a graphical interface, and initiated large-scale data transfer from the GODAE data server. The model was tuned to the CRAY X1 environment. The MPI communication was tuned mainly by the proper selection of the buffer length. Table 1 shows wall clock time of the forecast for two grids of moderate sizes (*193*x*121*x*30* grid points, 60h and *169*x*217*x*30* grid points, 48h). Comparison of results on two different machines (CRAY X1 and Opteron cluster) is very revealing. Using the Cray X1 with 32 single-streaming processors, we required 1 hour computer time for a 60 hour forecast. On the other hand, using our Linux cluster with 32 Opteron processors the same forecast is requires only two times more computer time. These results are very encouraging for the operational set up of the COAMPS system.

Table 1. Comparison of execution times on Cray X1 and Opteron cluster.

	2 proc	4 proc	9 proc	16 proc	32 proc
Cray X1	30426 s			6278 s	3803 s
Opteron cluster	53208 s	26625 s	12368 s	10923 s	6888 s

From the beginning of 2005, we have been testing different aspects of the operational set up of the system. We developed scripting software to control data transfer from the GODAE server. We are using NOGAPS global model results to specify lateral boundary conditions for all COAMPS runs. Also, we use NOGAPS fields to produce the initial conditions for all COAMPS runs. Our system employs five grids. The outer grid, with the spatial resolution of 39 km, covers all of Europe and the western portion of Asia. Within this grid, we defined three grids with resolutions of 13 km that cover Central Europe, Iraq, and Afghanistan (there are plans to use COAMPS to support deployment Polish military in these regions). The fifth grid is centered over Poland and has a spatial resolution of 4.3 km. Fig. 1, which is also our main www page for COAMPS forecasts, shows the geographical positions of these grids.

At present, we run the model two times a day. It takes about 3.8 hours on the Cray X1 to get the final 120h forecast for the coarse grid, the 72h forecasts on all of the 13 km grids, and the 24h forecast for the 4.3 km grid over Poland. The processing of data before the forecast (decoding, checking, and converting to the COAMPS flat files) and post-processing of results is done on a dedicated machine. The selected results are converted to a graphical form and presented on our internal WEB page. At the present time, the results of the COAMPS model runs at ICM are not available for public use, as more validation and verification of results is needed to assure the quality of our forecasts.

Fig. 2 shows the air temperature field at the 2 m level on our finest, 4.3 km grid. Colder mountainous areas and different circulations in the northern and southern parts of Poland are the most interesting features on this picture.

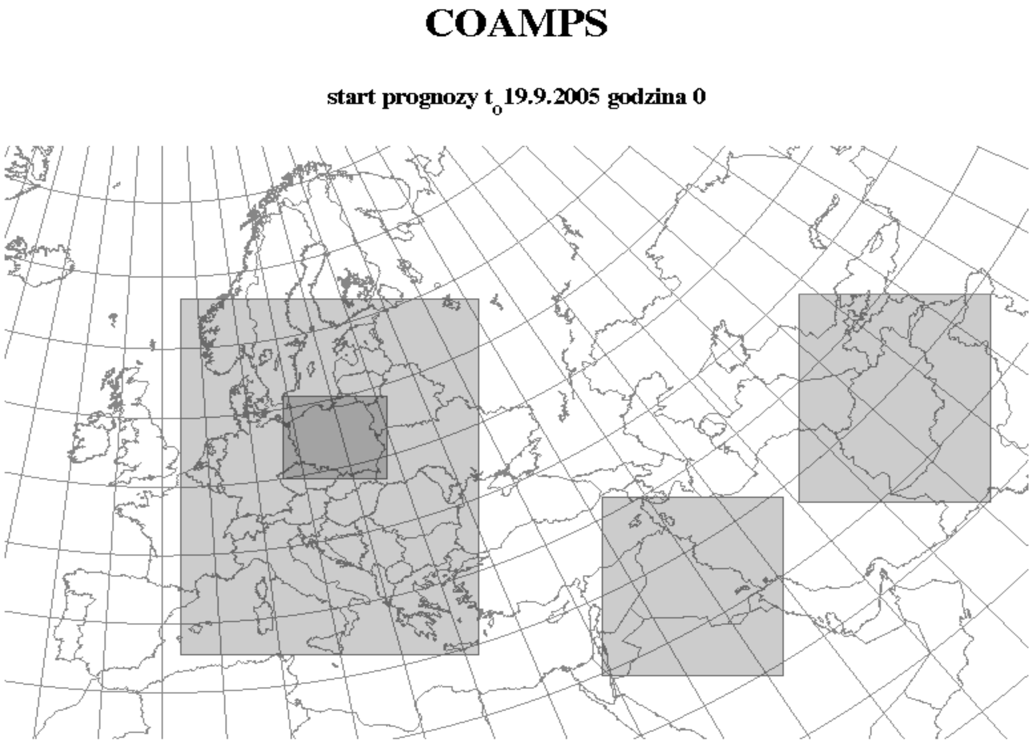

Figure 1 Operational configuration of the COAMPS system used in ICM.

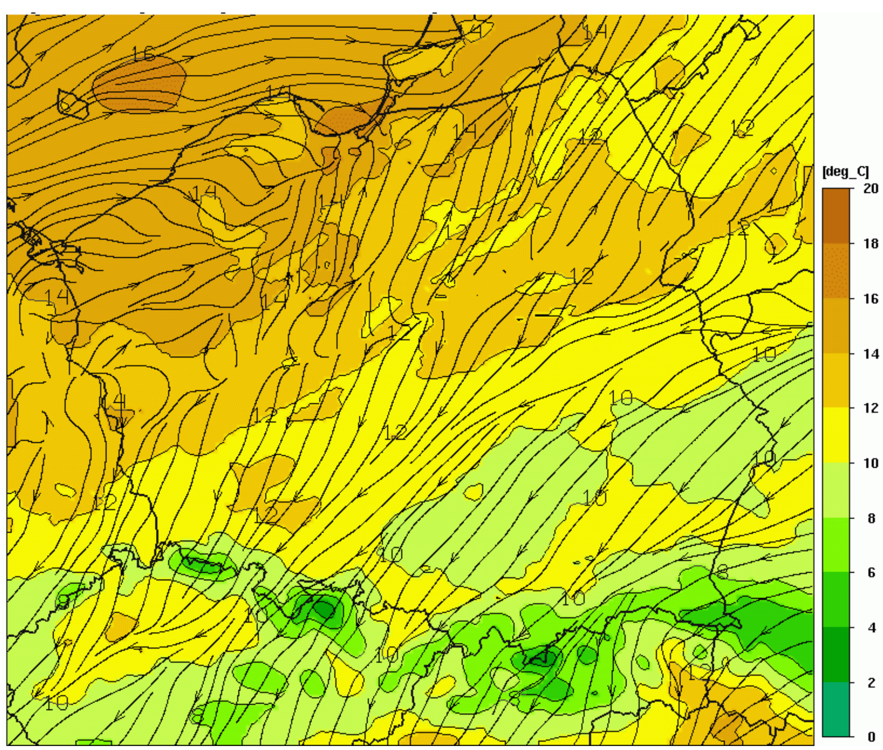

Fig. 2 Example of the COAMPS forecast for the finer (4.3 km) grid. This is an 18h forecast of air temperature and stream lines at the 2 m level. Starting time: 00Z 19 Sep 2005.

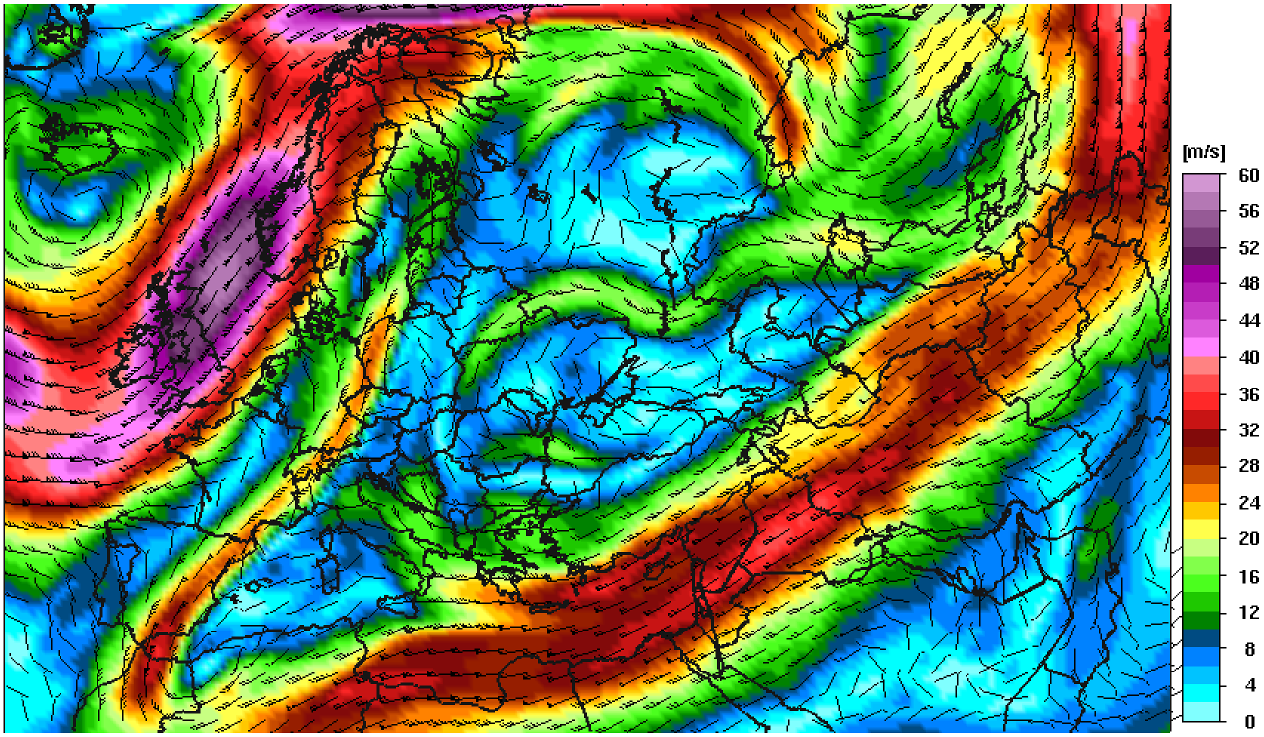

Fig. 3 Example of the COAMPS forecast for the outer, coarse (39 km) grid. This is a 42h 300 hPa wind forecast. Starting date: 12Z 25 Sep 2005.

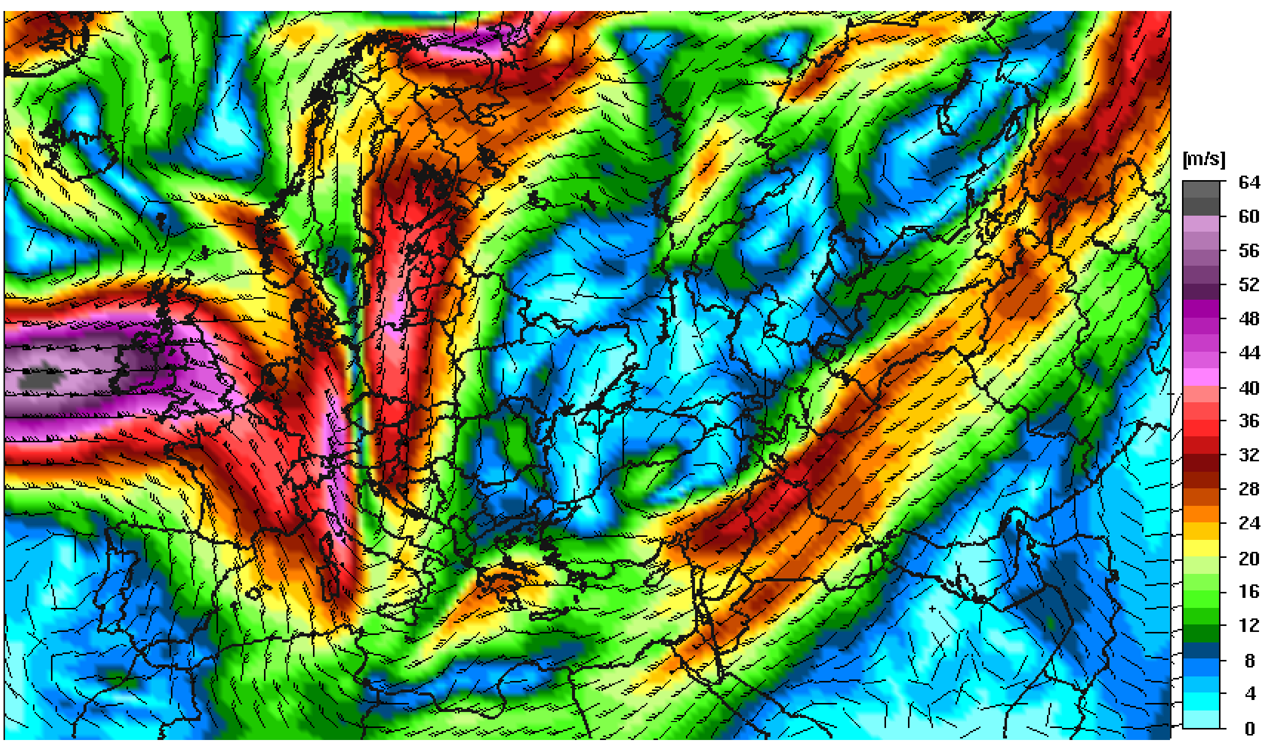

Fig. 4 Example of the COAMPS forecast for the outer, coarse (39 km) grid. This is a 120h 300 hPa wind forecast. Starting date: 12Z 25 Sep 2005.

Figures 3 and 4 show the wind fields at the 300 hPa level. Fig. 3 presents the 42 hour forecast. Two jet streams are visible, one over England and Scandinavia, and the second in Southern Europe. Fig. 4 shows a 120 hour forecast.

High-resolution model runs need new types of data to describe detailed features of the initial flow. Recently we began working on the assimilation of radar reflectivity and radial wind data in COAMPS. Our approach is to apply the ensemble Kalman filter scheme. In our preliminary tests, we performed the "twin-experiments" study, using the radar reflectivity and radial wind data created during a reference model run as the observations. These extracted "measurements" were assimilated next in a control run of the same model. In the forecast step of the Kalman filter we used the COAMPS model. In the analysis step of the filter, we applied software developed in NERC, Norway by Evensen (2003) for oceanographic applications. Details of these experiments will be presented on 11th Conference on Mesoscale Processes (Jakubiak, 2005).

In order to investigate the observational error characteristics for spatially correlated data we collected radar data in area around the Baltic Sea basin. These data consist of 22 months of radar composites with primary radar data every 15 minutes, and estimated precipitation patterns every 3 hours.

PERSONNEL EXCHANGES AND TRAVEL COMPLEMENTED

Richard Hodur, NRL – visited University of Warsaw (Poland), to present recent developments in COAMPS system and to discuss proposed set up of the COAMPS system at ICM. His experience in all aspects of the numerical weather prediction modeling was beneficial for the successful implementation of the COAMPS system in Poland.

Marcin Witek, University of Warsaw – visited NATO Undersea Research Centre (NURC, La Spezia, Italy) to work with Joao Teixeira on the preparation of the paper on stable and explicit diffusion and advection-diffusion numerical methods. We look at his work as one of the possible tools to improve the description of the advection-diffusion of aerosols in COAMPS.

Piotr Flatau, NRL – visited University of Warsaw (Poland) to discuss selected aspects of our NICOP project and to advise appropriate solutions (tools for model verification, interaction with related projects).

IMPACT/APPLICATIONS

The semi-operational version of the high resolution mesoscale model was implemented. This will improve 5-day forecasting for aviation and for support of Polish troops in Afghanistan and Iraq.

RELATED PROJECTS

2008 Peking Weather Demonstration Project Plans – We collected August 2005 observational data and relevant large scale data analyses and forecasts in anticipation of using COAMPS for the 2008 Olympics WWRP Demonstration Project for China in support of the Polish National Olympic team.

US GODAE project – The Global Ocean Data Assimilation Experiment (GODAE) provides regular, complete descriptions of the state of the ocean and the atmosphere in support of operational oceanography and oceanographic research. We use the GODAE server data in COAMPS predictions. The GODAE Monterey server is maintained by the FNMOC and is sponsored by the Office of Naval Research (ONR).

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